

CHAPTER 5

CONTROL-SYSTEM DESIGN VARIATIONS

1. GENERAL. The control systems shown in Chapter 4 will be modified when required to account for HVAC-system equipment variations. The variations covered in this chapter are as follows:

- a. 100 percent outside air systems.
- b. Control of exhaust fans.
- c. Smoke dampers.
- d. Variable speed drives.
- e. Steam preheat coil with face and bypass dampers.
- f. Modulating hot water or hot glycol preheat coil.
- g. Combining hydronic system and air system control systems in the same control panel.
- h. Unoccupied mode space temperature setback control for terminal units.
- i. Two-way shut-off valves on fan coil units.
- j. Building purge/flush cycle.
- k. EMCS initiated building purge and recirculation modes.
- l. Smoke control and freeze protection.
- m. Control systems without economizer modes.
- n. Dual steam valves.
- o. Hydronic systems with boilers requiring constant flow.

2. CONTROL SYSTEM VARIATIONS FOR 100 PERCENT OUTSIDE AIR (CONTINUOUS OPERATION).

a. HVAC systems that introduce 100-percent outside air are used as makeup air systems when large quantities of air are exhausted from the space. Such systems are used in the heating and cooling of such spaces as hospital operating rooms and laboratories, which cannot recirculate air from the space through the system. Spaces that cannot use return air will usually have more air exhausted than is supplied, to insure that the space is at a negative pressure with respect to surrounding spaces. This may be accomplished by an exhaust fan interlocked with the supply fan.

b. A 100-percent outside air system does not require the economizer changeover and mixed air temperature control loops, but does require an outside air preheat coil and associated temperature control loop in most climates.

c. The 100-percent outside air system may need a humidifier and its associated control loop. This loop would function identically as discussed in paragraph 3-9 and shown in figure 3-13.

d. Figure 5-1 shows the variations that would occur for a 100-percent outside air unit. The outside air preheat coil may be a heat recovery coil, which may be part of a glycol run-around system that recovers heat in the air from one or more exhaust fans. The heating coil will not be part of the recovery system. The system shown in figure 5-1 has a temperature/ humidity control sequence as described in Chapter 4. If the system has a heat recovery coil, some additional controls may be required if they are not part of a total heat recovery package. The exhaust fan is shown with a pneumatic damper actuator. Device EP-XX02 is shown as field-mounted, but it may be located in a local fan starter or may be included in the HVAC control panel. The designer will make this choice.

Figure 5-1. Schematic variations for 100-percent outside air systems.

e. The ladder diagram variations for the 100-percent outside air system are shown in figure 5-2, which is similar to figure 4-21B, but modified to delete the relay and pilot lights associated with the ventilation delay mode and with the system stops during the unoccupied mode. A smoke detector is required in the supply fan discharge. Figure 5-2 shows an exhaust fan section of the ladder diagram on lines 300 through 303. Each interlocked exhaust fan requires a contact of R-XX02 for safety shutdown and a remote safety override, located at assigned terminal blocks in the HVAC control panel.

Figure 5-2. Ladder diagram variations for 100-percent outside air systems.

3. CONTROL SYSTEM VARIATIONS FOR EXHAUST FANS.

a. Schematic variations for an exhaust fan are shown in figure 5-3, for electric and pneumatic actuators. Solenoid 3-way air valve EP-XX02 and damper actuator DA-XX02 will be energized to open their respective dampers when their respective fans start. These devices will be powered from a source other than the starter transformer, such as the HVAC control panel.

Figure 5-3. Schematic variations for exhaust fans.

b. Ladder diagram variations for exhaust fans are shown in figure 5-4. These variations are somewhat different from the exhaust fan interlock shown in figure 5-2, which are intended for exhaust fans that are interlocked to HVAC systems handling return air. One exhaust fan example is shown with a pneumatic damper operator, for guidance in applying pneumatic actuators to shutoff dampers. No positive positioner is required for the actuator. In this example, the fan is off and the dampers are closed in the unoccupied and ventilation delay mode. Another example is shown with an electric damper actuator, for guidance in applying electric actuators to shutoff dampers. In this example, the dampers are open whenever the supply fan runs. The designer will add relays in parallel with R-XX01, R-XX03, and R-XX11, as required to accommodate contacts to control additional exhaust fans. The designer will show contact and coil references on the schematic and the ladder diagram for the additional relays.

Figure 5-4. Ladder diagram variations for exhaust fans.

c. The designer will check the exhaust fan selection for the rated shutoff static pressure to determine whether a damper end switch should be applied to the control of the exhaust fan starter circuit. If the shutoff static pressure is 1 inch of water column or higher, the designer will incorporate an end switch in the design as described later in this manual under variations for smoke dampers.

4. CONTROL SYSTEM VARIATIONS FOR SMOKE DAMPERS.

a. Smoke dampers can be used with any HVAC air delivery system, but generally the smoke dampers are required only when the HVAC unit exceeds a given air capacity. An example of the use of smoke dampers is shown in figure 5-5. Actuators DA-XX04 and DA-XX05 will be powered from some source other than the fan starter holding coil transformer, such as the HVAC control panel. The contacts of relay R-XX12 must be closed to allow the smoke dampers to open.

Figure 5-5. Schematic variations for smoke dampers.

b. Figure 5-6 shows the ladder diagram variations for smoke dampers. When relay coil R-XX12 on line 105 is energized, contacts in the power circuits to DA-XX04 and DA-XX05 are closed allowing the smoke dampers to open. When the smoke dampers open, end switches ES-XX01 and ES-XX02 close their contacts on line 20 to energize relay coil R-XX11. When relay coil R-XX11 is energized, contacts on lines 104 and 204 close, to allow starter holding coils MO1 and MO2 to energize and start the fans. Tripping either end switch will shut down both fans. Relay coil R-XX12 is the only device that will be powered from the starter holding coil transformers. Relay coil R-XX12 must be wired through the overload relay contacts and must be powered in the "HAND" and "AUTO" positions of the "HAND-OFF-AUTO" switch; it also must be powered in the event that the remote safety override circuit is closed. Both dampers must open before either fan can start,

Figure 5-6. Ladder diagram variations for smoke dampers.

c. The designer will modify HVAC control panel layouts to show the relays and terminal blocks associated with these variations.

5. CONTROL SYSTEM VARIATIONS FOR VARIABLE SPEED DRIVES.

a. Figure 5-7a shows variable speed drives in lieu of the supply and return fan inlet vanes. Relay contacts in the supply duct static pressure control loop and the return fan volume control loop, which open on supply fan shutdown, are not necessary because there are no inlet vanes.

Figure 5-7a. Schematic variations for variable speed drives.

b. The variable speed drive must accept a 4 to 20 milliamperes signal as an input.

c. Figure 5-7b shows the ladder diagram variations for variable speed drives. It shows connections to the variable speed drive control circuits in lines 100 and up and in lines 200 and up. There is no magnetic starter in this case, because all starter functions are provided by the variable speed drive controller.

Figure 5-7b. Ladder diagram variations for variable speed drives.

d. Figure 5-7c shows variable speed drives in lieu of actuators for the inlet vanes.

Figure 5-7c. Equipment variations for variable speed drives.

e. Figure 5-7d shows the variations in the control panel interior door layout for variable speed drives. There are no receiver gauges in the interior door, because IPs for the inlet vanes are not required.

Figure 5-7d. Control panel interior door layout variations for variable speed drives.

f. Figure 5-7e shows the variations in the back panel arrangements for variable speed drives, with the bulkhead fittings for control of the dampers and the cooling coil valve. There is no need for bulkhead fittings for control of inlet vanes.

Figure 5-7e. Control panel back panel layout variations for variable speed drives.

g. The terminal block layout will show terminals assigned to the variable speed drive units rather than for the magnetic starter circuits for fans.

Figure 5-7f. Control panel terminal block layout variations for variable speed drives.

h. Figures 5-7g through 5-7j depict the use of variable speed drives in lieu of inlet guide vanes for a DDC system.

Figure 5-7g. DDC schematic variations for variable speed drives.

Figure 5-7h. DDC ladder diagram variations for variable speed drives.

Figure 5-7i. DDC schedule variations for variable speed drives.

Figure 5-7j. DDC I/O table and data terminal strip layout variations for variable speed drives.

6. CONTROL SYSTEM VARIATIONS FOR STEAM PREHEAT COIL WITH FACE AND BYPASS DAMPER.

a. The schematic diagram and ladder diagram additions to incorporate control for this type of preheat coil are shown in figure 5-8. The steam coil valve, VLV, is controlled from a 2-position thermostat, TSL, in the incoming outside air duct. The thermostat opens the steam valve when the outside air temperature drops to its setpoint and remains open as long as the outside air temperature is at or below the setpoint. The loop consisting of devices TT, TC, IP, and DA controls the air temperature in the discharge of the coil by modulating the preheat coil face and bypass damper to maintain the preheat coil discharge air temperature.

Figure 5-8. Control system variations for steam preheat coil with face and bypass dampers.

b. Thermometer TI in the outside air intake is required if there is not already such a device at an outside air temperature transmitter associated with an economizer controller.

c. The control devices and their parameters must be added to the equipment schedule.

7. CONTROL SYSTEM VARIATION FOR HOT WATER OR GLYCOL PREHEAT COIL. The loop to be added to control system schematics for modulating control of such preheat coils is as discussed in paragraph 3-3 and shown in figure 3-2. When required, this loop can be added to any HVAC system by showing the loop in the control system schematic, showing the loop devices and their parameters in the equipment schedule, and showing the controller and related devices in the control panel drawings.

8. CONTROL SYSTEM VARIATION FOR COMBINING HYDRONIC SYSTEM AND AIR SYSTEM CONTROLS IN THE SAME CONTROL PANEL. This variation is shown in Chapter 4 in the single-zone HVAC system with humidity control. Small buildings generally require a hydronic heating system or a dual-temperature water system and an air handling system. When appropriate, the designer will combine such systems into a common HVAC control panel.

9. UNOCCUPIED MODE SPACE TEMPERATURE SETBACK CONTROL FOR TERMINAL UNITS. In Chapter 4, the control systems for unit heaters and perimeter radiation are shown with room thermostats capable of one temperature setting. When the hydronic systems serving such units are controlled to maintain a reduced space temperature in the unoccupied mode, a microprocessor-based room thermostat will be substituted for the single-temperature thermostat shown in Chapter 4. Examples of the substitution are shown in figures 5-9 and 5-10.

Figure 5-9. Control system variations for unoccupied mode setback.

Figure 5-10. Control system variations for unoccupied mode setback.

10. CONTROL SYSTEM VARIATIONS FOR 2-WAY SHUTOFF VALVES FOR FAN COIL UNITS. For dual-temperature hydronic systems with variable flow pumping, the fan coil units will have 2-way shutoff valves in lieu of 3-way shutoff valves. The designer may show 3-way shutoff valves on selected fan coil units for pump relief of the variable flow pumping system. The schematic and ladder diagram variations are shown in figure 5-11.

Figure 5-11. Control system variations for 2-way shutoff valve on fan coil units.

11. CONTROL SYSTEM VARIATION FOR BUILDING PURGE / FLUSH CYCLE.

a. This variation provides the means to utilize a time-clock scheduled 100% outside air "building purge" cycle in situations such as laboratories, etc. where it is desirable to flush airborne contaminants on a regular basis. The "purge cycle" variation is applicable to all of the systems represented in figures 4-13x thru 4-22x. An example, as applied to the standard multizone system is shown in figures 5-12a through 5-12f. For a DDC control system, this variation can be incorporated by software changes, which should be reflected in the schedules and the sequence of operation.

b. The purge cycle utilizes a third set of contacts on the system timeclock for initiation. When this set of contacts close, a relay is energized to start the fan and a pilot light is turned on in the control panel. Once the fan is started, a solenoid valve (EP-XX-01) is energized, supplying main air to the mixed air dampers. This will move the outside air and relief air dampers to the fully open position, and the return air damper to the fully closed position; thereby supplying 100% outside air to the space. When the timeclock "purge" contacts open, ending the purge mode of operation, the system's mode of operation is determined by the remaining timeclock functions. Note that the purge mode of operation overrides the other modes, so far as the control of the mixed air dampers is concerned.

Figure 5-12a. Control system schematic for multizone HVAC system with building flush mode of operation.

Figure 5-12b. Control system ladder diagram for multizone HVAC system with building flush mode of operation.

Figure 5-12c. Control system equipment for multizone HVAC system with building flush mode of operation.

Figure 5-12d. Control panel interior door layout for multizone HVAC system with building flush mode of operation.

Figure 5-12e. Control panel back panel layout for multizone HVAC system with building flush mode of operation.

Figure 5-12f. Control panel terminal block layout for multizone HVAC system with building flush mode of operation.

12. CONTROL SYSTEM VARIATIONS FOR EMCS INITIATED BUILDING PURGE AND RECIRCULATION MODES.

a. When EMCS requires control of HVAC system outside air, return air, and relief air dampers, the devices used by EMCS to assume control of the dampers are external to the HVAC control panel. The devices required depend on whether the actuators are pneumatic or electric/ electronic.

b. Figure 5-13 shows the schematic variation for pneumatic actuators. The EMCS devices are: EPs labeled "EMCS", the purge/ auto and recirculating/auto contacts, and the associated control circuit. When EMCS is not in control, the EPs pass the pneumatic control signal from IP-XX01 to the PPs of the damper actuators. When the "PURGE/AUTO" contact is closed, main air passes through EP-1 to the PPs of the dampers, which causes the outside air damper to fully open. When the

"RECIRCULATING/AUTO" contact is closed, air is exhausted from the damper actuator PPs, causing the outside air damper to close. The return air and relief air dampers normally work in concert with the outside air damper. When both EMCS contacts are open, the EPs are de-energized and IP-XX01's pneumatic control signal is connected to the damper actuator's PPs.

Figure 5-13. Control system variations for EMCS building purge and recirculation modes for pneumatic actuators.

c. Figure 5-14 shows the EMCS devices required when the damper actuators are electric or electronic. The relays labelled "R-1 EMCS" and "R-2 EMCS" function in a manner similar to the EPs required for pneumatic actuators. The device labelled "EMCS MPS" is a minimum position switch set to hold the outside air damper open in the purge mode. The signal to the actuators is interrupted in the recirculating mode to close the outside air damper.

Figure 5-14. Control system variation for EMCS building purge and recirculation modes for electric or electronic actuators.

13. CONTROL SYSTEM VARIATIONS FOR SMOKE CONTROL AND FREEZE PROTECTION. In addition to the required HVAC control panels already shown, an HVAC system may have a smoke control and freeze protection panel, to house the equipment required to connect these systems to the HVAC control system. These systems can interrupt the control signals to starters, valves, and dampers for these special purposes. The smoke control and freeze protection panels, if required, will be custom designed specifically for each project. The standard HVAC control panels have interface provisions at terminal blocks for smoke control systems, freeze protection systems, or other external systems designed either to shut down the HVAC system or to bypass the shutdown circuits of the HVAC control system as required. The contract documents must show the interface requirements and locations of each non-HVAC control panel in the project. When direct digital controls are used to control an HVAC system, smoke control or freeze protection may be provided by a separate system as above, or these features can be integrated into one system.

14. CONTROL SYSTEM VARIATIONS FOR NON-ECONOMIZER HVAC SYSTEMS.

a. The economizer mode of operation is not appropriate for every HVAC application. When an HVAC system is designed for comfort applications without humidity control (i.e., no humidification or dehumidification), the control system will have a minimum-position switch to allow some adjustment of the mixed air flow. The steps involved in modifying a standard single-zone economizer mode control system (such as shown in Chapter 4) to convert it to a non-economizer control system are:

(1) Delete all economizer loop devices (such as the economizer controller and its transmitter, relay contacts, and signal selector) from the control system schematic.

(2) Delete the economizer's PV and DEV contacts and their associated relay and pilot light from the ladder diagram.

(3) Delete the economizer controller and associated devices from the equipment schedule.

- (4) Delete the economizer controller from the interior door layout.
 - (5) Delete the signal selector and relays associated with the economizer controller from the back panel layout.
 - (6) Delete the economizer controller terminals from the terminal block layout.
- b. Control systems other than a single-zone control system can be modified to delete the economizer mode by deleting additional devices as follows:
- (1) Delete the mixed air temperature control loop and associated devices from the schematic.
 - (2) Delete the mixed air temperature controller and associated devices from the equipment schedule.
 - (3) Delete the mixed air temperature controller from the interior door layout.
 - (4) Delete the mixed air temperature controller terminal blocks from the terminal block layout.
- c. To show the results of the previously described procedures, the single-zone system shown in figures 4-19a through 4-19j has been modified to show a single-zone, non-economizer control system as figures 5-15a through 5-15j.

Figure 5-15a. Control system schematic for single-zone HVAC system without economizer control mode.

Figure 5-15b. Control system ladder diagram for single-zone HVAC system without economizer control mode.

Figure 5-15c. Control system equipment for single-zone HVAC system without economizer control mode.

Figure 5-15d. Control panel interior door layout for single-zone HVAC system without economizer control mode.

Figure 5-15e. Control panel back panel layout for single-zone HVAC system without economizer control mode.

Figure 5-15f. Control panel terminal block layout for single-zone HVAC system without economizer control mode.

Figure 5-15g. DDC control system schematic for single-zone HVAC system without economizer control mode.

Figure 5-15h. DDC control system ladder diagram for single-zone HVAC system without economizer control mode.

Figure 5-15i. DDC control system equipment for single-zone HVAC system without economizer control mode.

Figure 5-15j. DDC control system I/O table and data terminal strip layout for single-zone HVAC system without economizer control mode.

15. CONTROL SYSTEM VARIATIONS FOR DUAL STEAM VALVES. Generally when the size of a steam control valve exceeds 65 mm (2-1/2 inches) (pipe size) or when there is a seasonal requirement for low flow, two steam valves will be used to enhance control authority. Usually the valves are sized for 1/3 of the total flow and 2/3 of the total flow. The valve K_v s (C_v s) will be selected from available products with one valve having a smaller K_v (C_v). The valves are then sequenced without a control signal deadband. The control signal range available for operating the valves is to be split into two parts - one third of the signal range (21 to 48 kPa (3 to 7 psi)) is used to modulate the smaller valve and two thirds (48 to 103 kPa (7 to 15 psi)) of the signal range is used to modulate the larger valve. In the control sequence, the smaller control valve opens first. The control system drawings affected are the schematic and the equipment schedule. Figures 4-10a and 4-10c have been modified to show the required changes and are shown as figures 5-16 and 5-17.

Figure 5-16. Schematic variations for dual steam valves.

Figure 5-17. Equipment schedule variations for dual steam valves.

16. CONTROL SYSTEM VARIATIONS FOR HYDRONIC SYSTEMS WITH BOILERS REQUIRING CONSTANT FLOW. Figures 4-8a through 4-8j and 4-12a through 4-12j depict single building hydronic systems which vary the flow through the boiler. However, some boilers will not tolerate low-flow conditions. Figures 5-18a through 5-18j and 5-19a through 5-19j show variations of these systems which maintain a constant flow rate through the boiler. The variations consist of adding an additional piping loop around the boiler and an additional pump.

Figure 5-18a. Control system schematic for single building hydronic heating system with constant volume hot water boiler loop.

Figure 5-18b. Control system ladder diagram for single building hydronic heating system with constant volume hot water boiler loop.

Figure 5-18c. Control system equipment for single building hydronic heating system with constant volume hot water boiler loop.

Figure 5-18d. Control panel interior door layout for single building hydronic heating system with constant volume hot water boiler loop.

Figure 5-18e. Control panel back panel layout for single building hydronic heating system with constant volume hot water boiler loop.

Figure 5-18f. Control panel terminal block layout for single building hydronic heating system with constant volume hot water boiler loop.

Figure 5-18g. DDC control system schematic for single building hydronic heating system with constant volume hot water boiler loop.

Figure 5-18h. DDC control system ladder diagram for single building hydronic heating system with constant volume hot water boiler loop.

Figure 5-18i. DDC control system equipment for single building hydronic heating system with constant volume hot water boiler loop.

Figure 5-18j. DDC control system I/O table and data terminal strip layout for single building hydronic heating system with constant volume hot water boiler loop.

Figure 5-19a. Control system schematic for single building dual-temperature hydronic system with constant volume boiler loop.

Figure 5-19b. Control system ladder diagram for single building dual-temperature hydronic system with constant volume boiler loop.

Figure 5-19c. Control system equipment for single building dual-temperature hydronic system with constant volume boiler loop.

Figure 5-19d. Control panel interior door layout for single building dual-temperature hydronic system with constant volume boiler loop.

Figure 5-19e. Control panel back panel layout for single building dual-temperature hydronic system with constant volume boiler loop.

Figure 5-19f. Control panel terminal block layout for single building dual-temperature hydronic system with constant volume boiler loop.

Figure 5-19g. DDC control system schematic for single building dual-temperature hydronic system with constant volume boiler loop.

Figure 5-19h. DDC control system ladder diagram for single building dual-temperature hydronic system with constant volume boiler loop.

Figure 5-19i. DDC control system equipment for single building dual-temperature hydronic system with constant volume boiler loop.

Figure 5-19j. DDC control system I/O table and data terminal strip layout for single building dual-temperature hydronic system with constant volume boiler loop.